10/551339

JC09 Rec'd PCT/PTO 29 SEP 2005

Attorney Docket No. 2003P00537WOUS

CERTIFICATION OF ATTACHED ENGLISH TRANSLATION OF PCT APPLICATION:

PCT/EP2004/003607 BASED ON DE 103 15 523.6, Filed 04/04/2003

I hereby certify the English translation attached is a true and accurate copy of the referenced PCT/EP2004/003607 application.

John T. Winburn
September 29, 2005
Reg. No. 26,822

Refrigeration device with adaptive automatic defrosting and corresponding defrosting method

The present invention relates to a refrigeration device comprising an automatically defrostable evaporator and a defrosting method therefor. In so-called no-frost refrigeration devices, an evaporator which serves to cool an inner chamber of a thermally insulating housing which can be filled with chilled goods, is accommodated in a chamber separate from the inner chamber, communicating with the inner chamber by means of air passage openings. Together with the air passage openings this chamber forms an air passage through which air is circulated in order to be cooled on the evaporator and returned to the inner chamber again.

The installation of the evaporator in the separate chamber allows the evaporator to heat and thereby defrost when a critical quantity of ice has formed thereon whilst the air circulation between the evaporator chamber and the inner chamber is switched off in order to prevent the inner chamber with the chilled goods located therein, from being heated at the same time as the chamber.

For an economical operating mode of such a refrigeration device it is important that the evaporator is reliably defrosted as soon as a critical quantity of ice on the evaporator is exceeded since the ice insulates the evaporator from the chamber surrounding it and thus adversely influences the efficiency of the cooling. The housing structure of such a refrigeration device generally does not allow a user to look into the evaporator chamber to check the quantity of ice and decide whether a defrosting is necessary or not. An automatic control of the defrosting is thus required.

It would be desirable to be able to directly measure the thickness of an ice layer on the evaporator and using this thickness, decide automatically whether a defrosting is necessary or not. However, sensors to record the ice thickness are costly and their lifetime is significantly shorter than that of the other components of conventional refrigeration devices so that their use would significantly increase their liability to repair.

For this reason, in most of the present no-frost refrigeration devices a time-controlled defrosting method is used, i.e., a control circuit of the refrigeration device triggers a defrosting process in each case at fixed time intervals. This technique is certainly robust and inexpensive but has the disadvantage that it is not possible to adapt to different climatic conditions under which the refrigeration device is operated. That is, an on average "appropriate" time interval between two defrosting processes can easily be too long if the device is operated in a warm environment where a large quantity of moisture is carried into the inner chamber every time the door is opened and the ice layer on the evaporator consequently grows rapidly whereas when the refrigeration device is operated in a cold environment with little moisture carried in, a time interval longer than that set could improve the economic efficiency of the refrigeration device. In addition, this technique cannot take into account the fact that the moisture intake depends not only on the running time of the device but also on the number of times the door is opened and on the type of chilled goods stored in the device.

It is the object of the invention to provide a refrigeration device which allows a reliable assessment of

the quantity of ice accumulated on an evaporator using simple and robust means or a method which allows a reproducible defrosting whenever a given quantity of ice is reached on the evaporator.

The object is solved by a refrigeration device having the features of claim 1 and a method having the features of claim 10.

The invention uses the fact that the free cross-section of the air passage in which the evaporator is located is limited and tends to decrease as the quantity of ice deposited on the evaporator increases. By recording the change in the air flow through the passage resulting therefrom, the quantity of ice and thus the need for a defrosting process can be indirectly inferred.

Various techniques can be considered to record the air flow through the channel. The most direct technique probably involves arranging a body which can be driven to move by the air flow in the channel and allocating a sensor to said body to record the motion. If the air flow in the channel decreases so far that it falls below a predetermined velocity threshold, this means that a defrosting is necessary.

Instead of a movable element, an elastic element can also be provided in the air passage, which is merely statically deflected by the air flow and this deflection is recorded by a sensor. In this case, a defrosting process is recognised as necessary if the deflection of the elastic element falls below a predetermined threshold value.

Another possibility for recording the air flow is to use the Bernoulli effect, i.e. the fact that a lower

hydrostatic pressure is measured at a flowing medium than at a stationary medium. In order to obtain the largest possible measurement signal here, a bottleneck at which particularly high flow velocities occur can be provided in the air passage and a pressure sensor can be placed in the vicinity of this bottleneck.

Another possibility is to use heat gradients influenced by the air flow in the passage. Two temperature sensors are required for this purpose, these sensors being thermally differently closely coupled to a heat source or sink or to the air in the passage. The lower the air flow in the passage which brings about a temperature balance, the larger are the temperature differences which can occur between these two sensors. Consequently a critical reduction in the air flow is then determined when the difference between the temperatures recorded by the two sensors exceeds a threshold value.

An electrically heated wire can be considered as a heat source for this embodiment of the invention, as is also known from air flow measuring devices in automobile construction. The heat output of such a wire can be so low that it does not significantly impair the energy balance of the refrigeration device. Preferably however, the evaporator itself, which is necessarily present, is used as a heat sink.

In order to be able to record the largest possible temperature difference, a first one of the temperature sensors is preferably arranged directly on the evaporator.

It is especially preferable if this temperature sensor is placed on an area of the evaporator capable of icing up so that an insulating layer of ice which optionally covers the

temperature sensor even further amplifies the temperature difference measurable between the two temperature sensors with increasing layer thickness.

The second temperature sensor is preferably arranged at an output of the passage.

Further features and advantages of the invention are obtained from the following description of the exemplary embodiments with reference to the appended figures. In the figures:

Fig. 1 is a schematic section through a refrigeration device according to a first embodiment of the invention;

Fig. 2 shows a detail of the air passage according to a second embodiment of the invention;

Fig. 3 shows a detail of the air passage according to a third embodiment of the invention;

Fig. 4 shows an air flow measuring device according to a fourth embodiment of the invention; and

Fig. 5 shows a partial section through the housing of a refrigeration device according to a fifth embodiment of the invention.

Figure 1 is a highly schematic diagram showing a no-frost refrigeration device according to a first embodiment of the invention. The refrigeration device comprises, in a conventional fashion, a thermally insulating housing 1 in which is formed an inner chamber 2 for receiving chilled goods and an evaporator chamber 5 separated from the inner chamber 2 by an intermediate wall 3 and communicating with

the inner chamber 2 through openings in the intermediate wall 3. Located in the evaporator chamber 5 is a plate-shaped evaporator 7 supplied with coolant by a refrigerating machine 6 and in close contact therewith, a defrosting heater 8.

The evaporator chamber 5 and the openings 4 are jointly designated as an air passage. A control circuit 10 controls the operation of the refrigerating machine 6 and a fan 11 attached to the upper opening 4 by means of a measured signal from a temperature sensor (not shown) in the inner chamber 2. Refrigerating machine 6 and fan 11 can each be operated at the same time; it is preferable if the fan 11 is respectively switched on and off with a certain delay with respect to the refrigerating machine 6 in order to first give the evaporator 7 the opportunity to cool down before air is circulated when the refrigerating machine is started up and in order to use the residual coldness of the evaporator 7 after switching off the refrigerating machine 6.

Located in the lower opening 4 is a wind wheel 12 which is driven to turn by the air flow caused by the fan 11 and its rotation is recorded by an incremental encoder 13 connected to the control circuit 10. Using the signals of the incremental encoder 13, the control circuit is able to assess the turning speed of the wind wheel 12 and thus the air flow through the air passage. If this turning speed falls below a predetermined threshold value, this is an indication that the free cross-section of the evaporator chamber 5 is significantly reduced by ice formation on the evaporator 7 and that a defrosting process is required.

For defrosting the control circuit 10 applies a heating current to the defrosting heater 8 via a switch 9 for a

predetermined time interval. The time interval is selected so that the quantity of heat released by the defrosting heater 8 in this time is sufficient to completely defrost the ice layer on the evaporator. Since the thickness of the ice layer at which the control circuit 10 triggers a defrosting process is substantially always the same, the quantity of thermal energy required for defrosting is also substantially constant and adaptive regulation of the defrosting time is not necessary.

If the wind wheel 12 jams, this can incorrectly have the result that a defrosting process is recognised as necessary and is triggered. The probability of jamming can be reduced by briefly operating the fan 11 at a higher speed when starting up compared with its permanent operating speed in order to ensure that the air flow incident at the wind wheel 12 is strong enough to set this in rotation. It is also feasible that the control circuit 10 is capable of discriminating between an abrupt drop in the turning speed of the wind wheel 12 and a gradual decrease and in the first case briefly operating the fan 11 at elevated speed and, if no turning is recorded thereafter, generating a fault message.

Figure 2 shows a section from the air passage, e.g. at the height of one of the openings 4 according to a second embodiment of the invention. Anchored in the wall of the passage is a flexible lamella 14 which projects into the passage and is deflected by an air flow from a rest position shown by the dashed lines into an elastically bent position shown by the continuous lines. This position of the lamella is recorded by a proximity sensor 15 arranged in the passage, e.g., in the form of a resonant circuit comprising a coil 16 whose resonance frequency is influenced by the distance of the lamella 14 from the coil

16. Since no continuously moved parts are present in this embodiment, their wear is low and the reliability high.

Figure 3 shows a section of the air passage according to a third embodiment of the invention. The air passage is locally constricted here to form a nozzle 17 on the outflow side of which a chamber 19 is formed with a pressure sensor 18 located therein. The high speed of the air flow on the outlet side of the nozzle 17 causes a severe reduction in pressure in the chamber 19 in the fashion of an ejector pump, which can be recorded using the pressure sensor 18. The control circuit connected to the pressure sensor 18 is thus able to estimate the flow velocity of the air and thus the throughput through the air passage and trigger a defrosting process if the air flow reaches a critical low value.

In the fourth embodiment of the invention shown with reference to Fig. 4 two wires 20, 21 with a temperature-dependent resistance value are arranged in the air passage. A measuring circuit 22 or 23 is associated with each wire 20, 21. The measuring circuit 22 applies a low measuring voltage to the wire 20, measures the current flow through the wire 20 resulting therefrom and determines the corresponding resistance or temperature value of the wire 20. The voltage applied to the wire 20 is selected to be so low that the heating of the wire 20 resulting from the current flow is negligible.

The first measuring circuit 22 supplies the temperature value obtained to the control circuit 10. This circuit supplies a desired temperature value increased by a fixed difference compared thereto to the second measuring circuit 23. This circuit regulates the voltage which it applies to the wire 21 so that this acquires the desired temperature.

The temperature of the wire 21 is recorded by the measuring circuit 23 in the same way as the measuring circuit 22 by means of the resistance of the wire. The value of the heat output required for this purpose is fed by the measuring circuit 23 back to the control circuit 10. The heat output is higher, the larger the air flow through the air passage. If it falls below a predetermined threshold value, the control circuit 10 recognises that a critical quantity of ice is reached and triggers a defrosting process.

A fifth embodiment of the invention is shown in Fig. 5 using a partial section of a refrigeration device housing. The structure of the housing substantially corresponds to that described with reference to Fig. 1 so that elements designated by the same reference symbols in both figures are not described again. In the embodiment in Fig. 5 the wind wheel and the incremental encoder are omitted in the lower opening 4 of the air passage; instead, a temperature sensor 24 or 25 is attached respectively in the upper opening forming the output of the air passage and on the plate of the evaporator 7. A hatched area designates an ice layer 26 which can form around the evaporator and the defrosting heater 8. If the evaporator 7 is ice-free, the free passage cross-section of the evaporator chamber 5 is relatively large and an air flow required for effective cooling of the inner chamber 2 can be achieved at low flow velocity and a correspondingly long dwell time of the air in contact with the evaporator 7. The cooling of the air on the evaporator 7 is thus intensive and the difference between the temperatures recorded by the sensors 24, 25 is small.

As the thickness of the ice layer 26 on the evaporator 7 increases, the free cross-section of the evaporator chamber 5 decreases. Likewise, the air flow decreases and the flow

velocity in the evaporator chamber 5 increases. Consequently, the time available for cooling the air is shortened and the difference between the temperatures recorded by the sensors 24, 25 increases.

If, as is shown here, the temperature sensor 25 is attached at a position of the evaporator 7 at which ice can accumulate, the ice layer 26 itself additionally contributes to increasing the temperature difference between the two sensors. If this temperature difference exceeds a predetermined threshold value, the control circuit 10 connected to the sensors 24, 25 triggers a defrosting process.